Methyl Tertiary Butyl Ether (MTBE) Impacts to California Groundwater

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USEPA Blue Ribbon Panel

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Lawrence Livermore National Laboratory

Happel, Dooher & Beckenbach, 1999

Project Objective:

Perform quantitative analysis of environmental data in order to provide California Governor's Office, legislature, and public entities with information concerning the vulnerability of California's groundwater to Methyl Tertiary Butyl Ether (MTBE).

An Evaluation of MTBE Impacts to California Groundwater Resources

Happel, Beckenbach, and Halden
June 11, 1998
UCRL-AR-130897

- <u>MTBE is a frequent and widespread contaminant in shallow groundwater throughout California</u>-

  > 10,000 leaking underground tank sites with MTBE.

- <u>MTBE plumes are more mobile and recalcitrant than benzene plumes</u>

- <u>MTBE has the potential to impact regional groundwater resources and may present a cumulative contamination hazard.</u>
  MTBE contamination of public drinking water supplies may be a progressive problem. Water resource management on the regional scale will become increasingly relevant.

Happel, Dooher & Beckenbach, 1999

UCRL-MI-133696

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I. Occurrence Data:

MTBE detections at California LUFT Sites

Comparison of maximum MTBE Concentrations detected at LUFT sites throughout California

ppb (parts per billion)	'95 - '96 236 Sites	January '99 4300 Sites
<5	25%	23%
5-50	11%	12%
50-200	11%	11%
200-1000	18%	17%
1000-5000	16%	14%
5000-20000	13%	13%
20000-100000	4%	7%
>100000	1%	3%

Happel, Dooher & Beckenbach, 1999

Leaking Underground Fuel Tank Sites in California: Results of MTBE Analysis (January 1999)

Presence of MTBE at Open-Case LUFT Sites:

	Total LUFT Sites
MTBE Detects	4,613
MTBE Non Detects	1,514
Unknown or Not Reported	9,960

Percent of Open-Case Sites Impacted by MTBE: 75.3%
Estimated Current Total Impacted Site: Greater than 10,000

II. Plume Behavior:

Time series analysis of relative mobility and recalcitrance

Happel, Dooher & Beckenbach, 1999

Time Series Data Set

- Time series data was voluntarily submitted by industry for 29 LUFT sites in San Diego County. (1993-96)

- Records include 327 wells with a total of 2320 coincident samples of MTBE, BTEX and TPH.

- Is the data set representative of typical California LUFT sites?

Approach

- Statistical analysis of time series field data for comparison of MTBE and BTEX / TPH plume evolution.

Measure of Contaminant Association Over Time

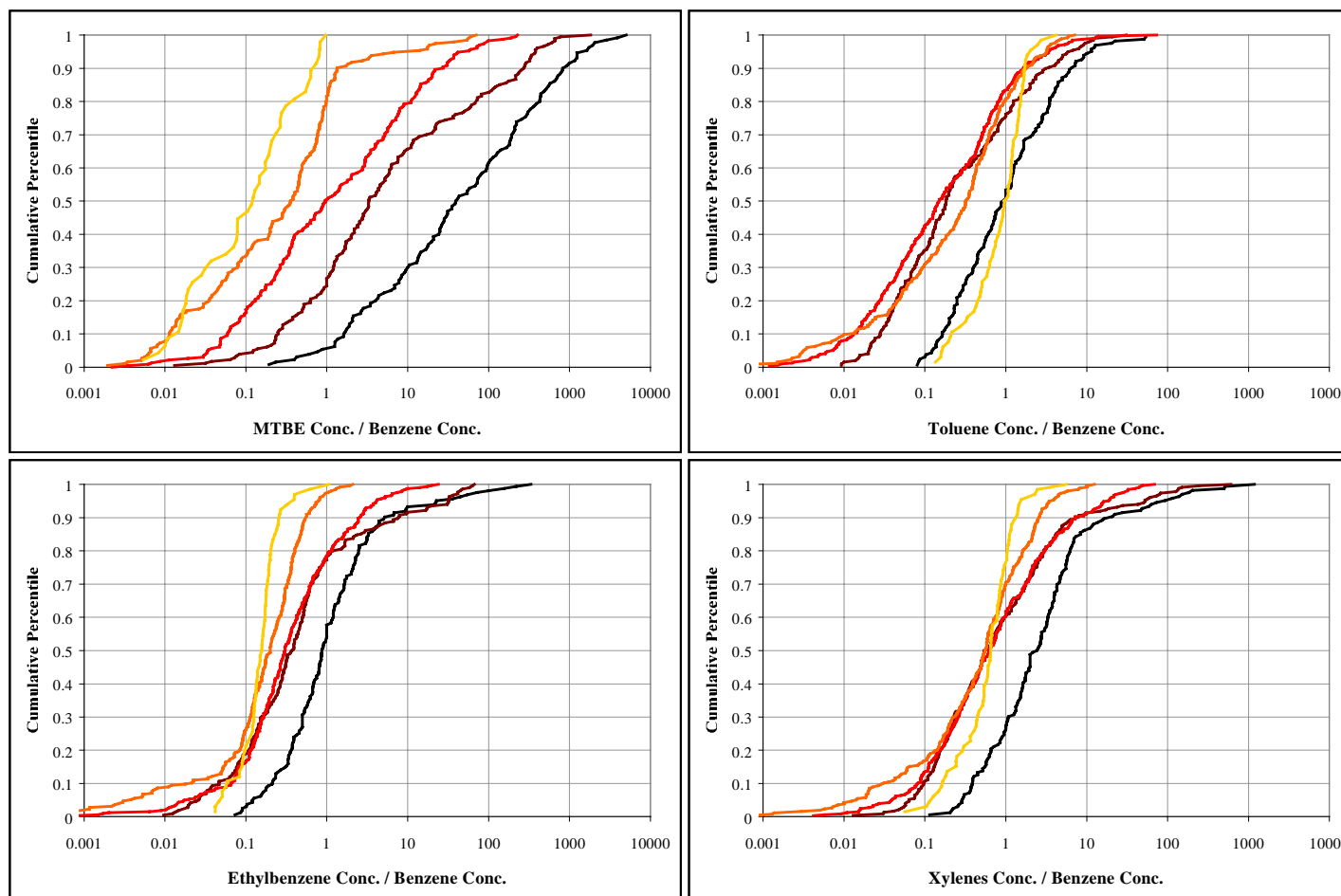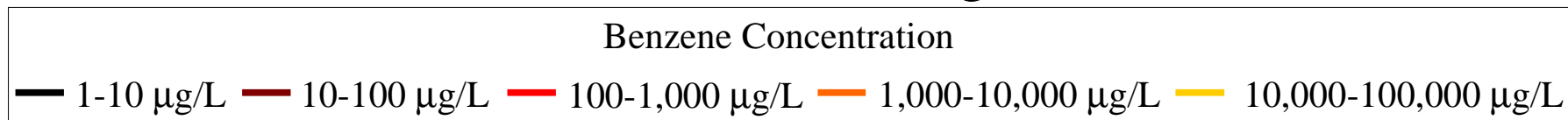**Probability of Detection Given Benzene at > 1.0 ppb**
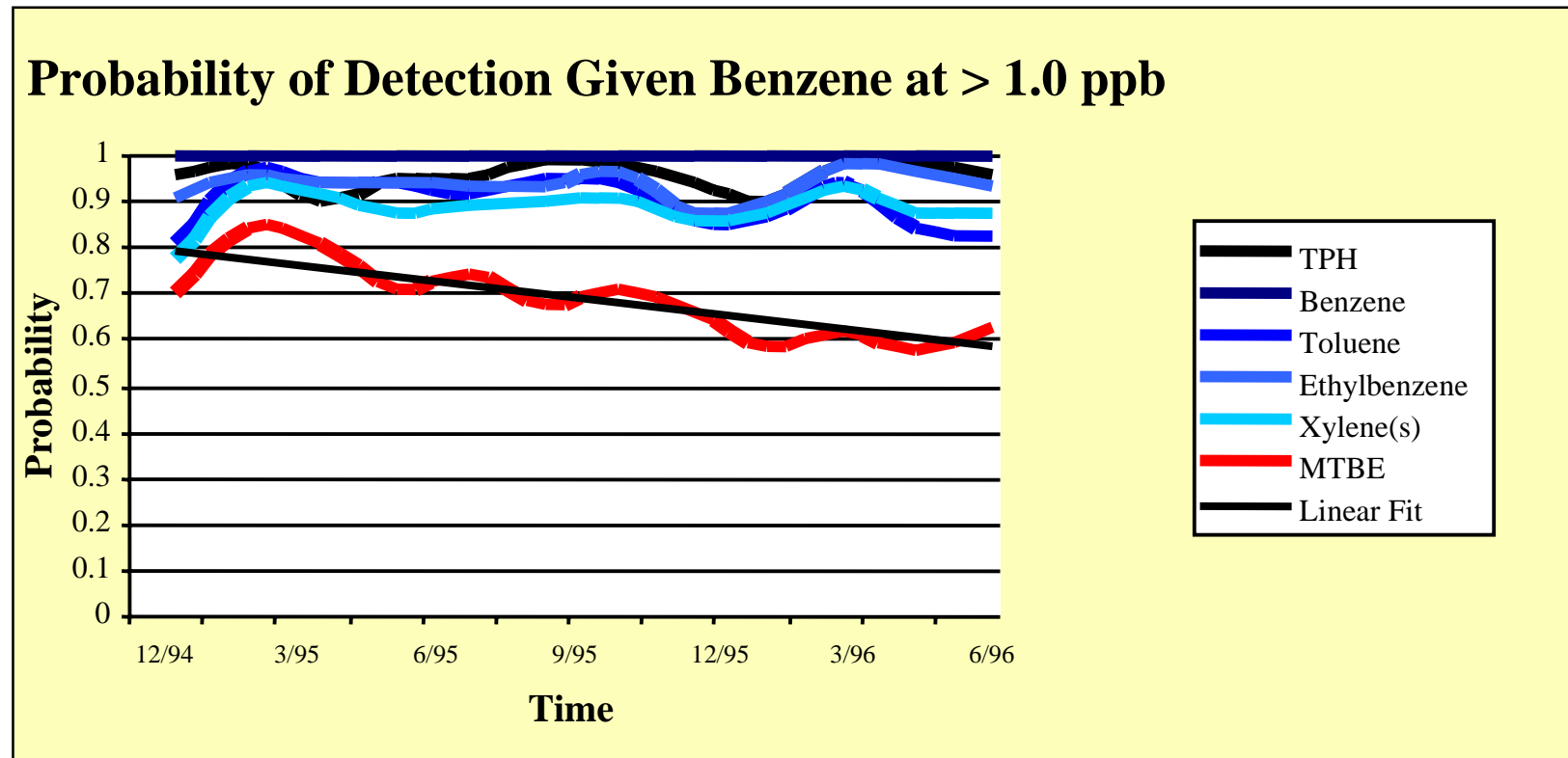
- If one detects benzene in a monitoring well (> 1.0 ppb), will MTBE (> 5.0 ppb) also occur?
- Over time, ~3 years, the association between MTBE and benzene decreases by ~20%.

MTBE and Benzene plumes are "disassociating" over time

Happel, Dooher & Beckenbach, 1999

Relative Concentration Ratios of MTBE to Benzene in LUFT Monitoring Wells

Happel, Dooher & Beckenbach, 1999

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Given the widespread distribution of MTBE sources throughout California-

How do we prevent future contamination of public groundwater sources?

III. Geographical Information System (GIS):

System development and current state-wide MTBE data

Happel, Dooher & Beckenbach, 1999

Senate Bill 1189 and Assembly Bill 592 (1997)

The State Water Resources Control Board shall...

Initiate a state-wide geographical information system (GIS) to manage the threat of MTBE contamination to public groundwater supplies.

- LLNL is the contractor for this project.

- This system must collect, store, retrieve, analyze, and display environmental geographic data in a database that is accessible to the public.
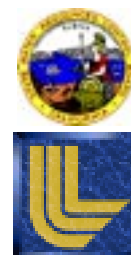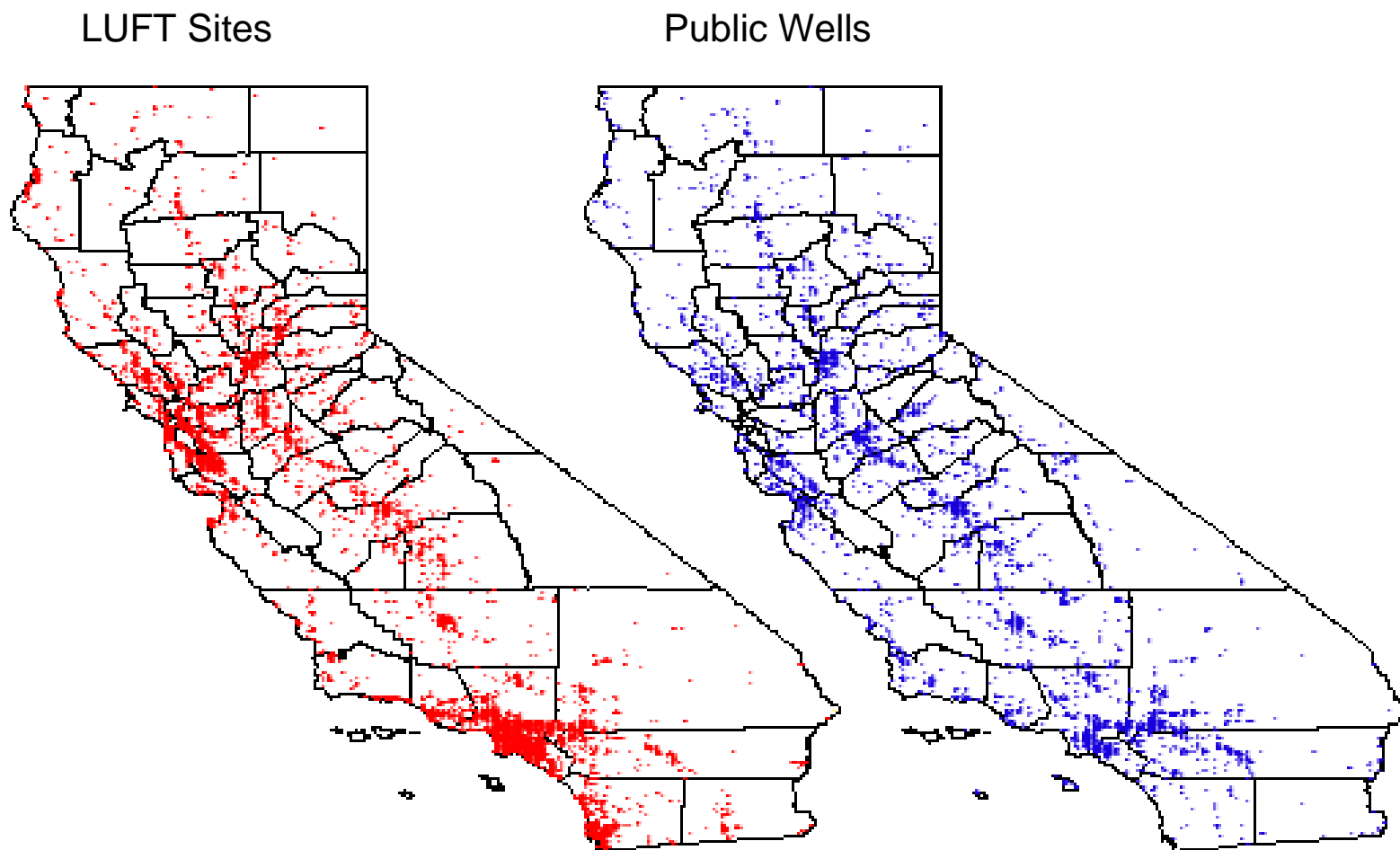
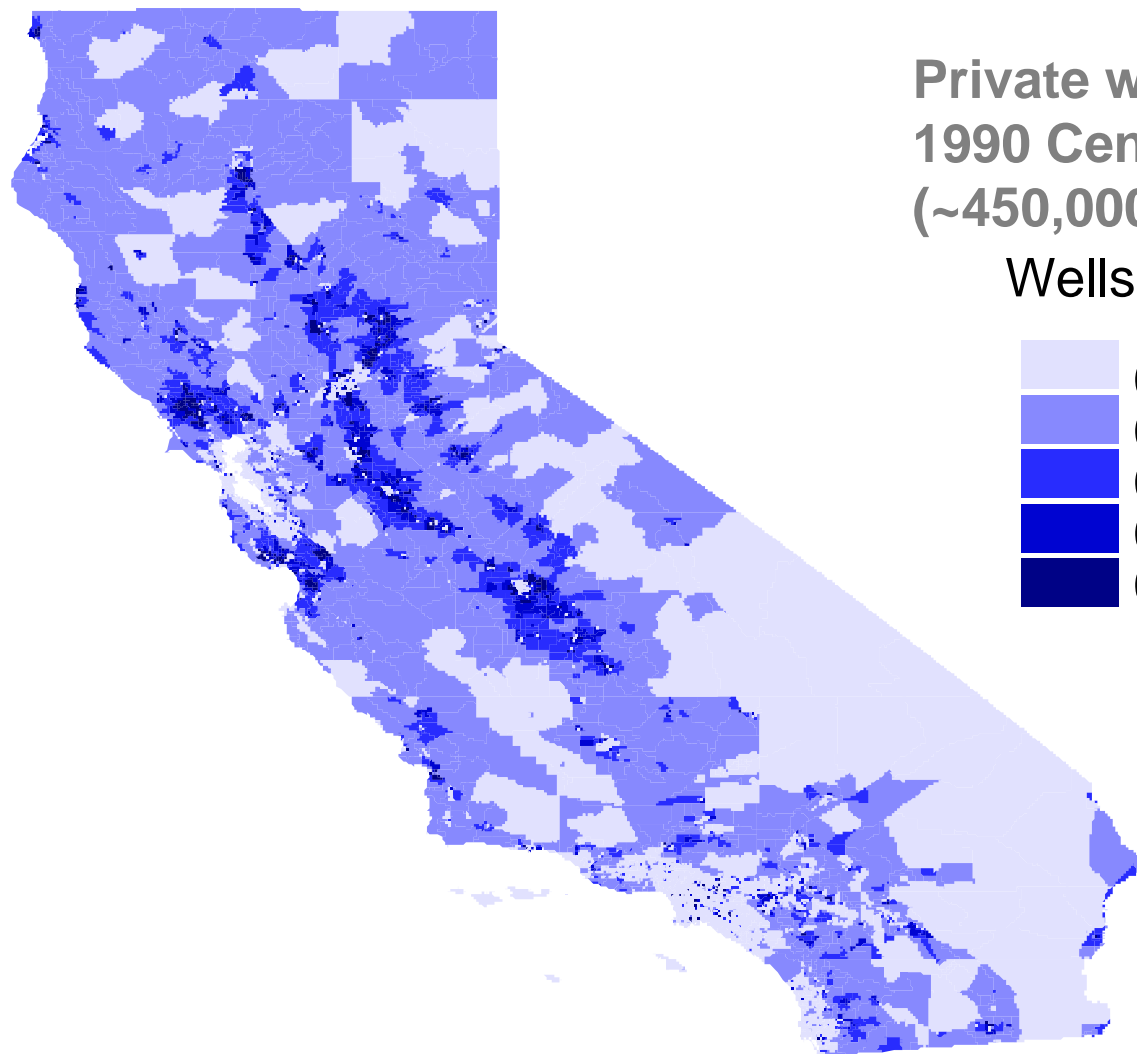# State Water Resources Control Board GIS database

- **Provides detailed information for leaking tank sites and public water supplies**

  - Provides specific information needed by the water board case worker to manage site clean-up.

  - Tracks information on tank & piping construction and leak detection systems present at each facility.

  - Maintains information on water production and water quality data (analytical monitoring results for groundwater and surface water samples).

  - Allows oversight management of leaking storage tanks by all interested parties (regulators, water purveyors, the petroleum industry…).

Happel, Dooher & Beckenbach, 1999

Locations of leaking underground fuel tanks (LUFTs) and public wells in California

LUFT Sites

Public Wells

Happel, Dooher & Beckenbach, 1999

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Density of private wells in California
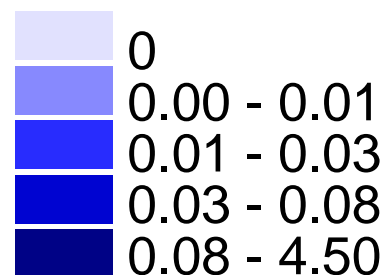
Private well density based on 1990 Census Block Group Data (~450,000 Private Wells)

Wells per Acre

- 0
- 0.00 - 0.01
- 0.01 - 0.03
- 0.03 - 0.08
- 0.08 - 4.50

Happel, Dooher & Beckenbach, 1999

Co-locations of private water wells with leaking underground tanks

Specific Vulnerability

- Very Low
- Low
- Moderate
- High
- Very High

Happel, Dooher & Beckenbach, 1999
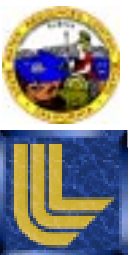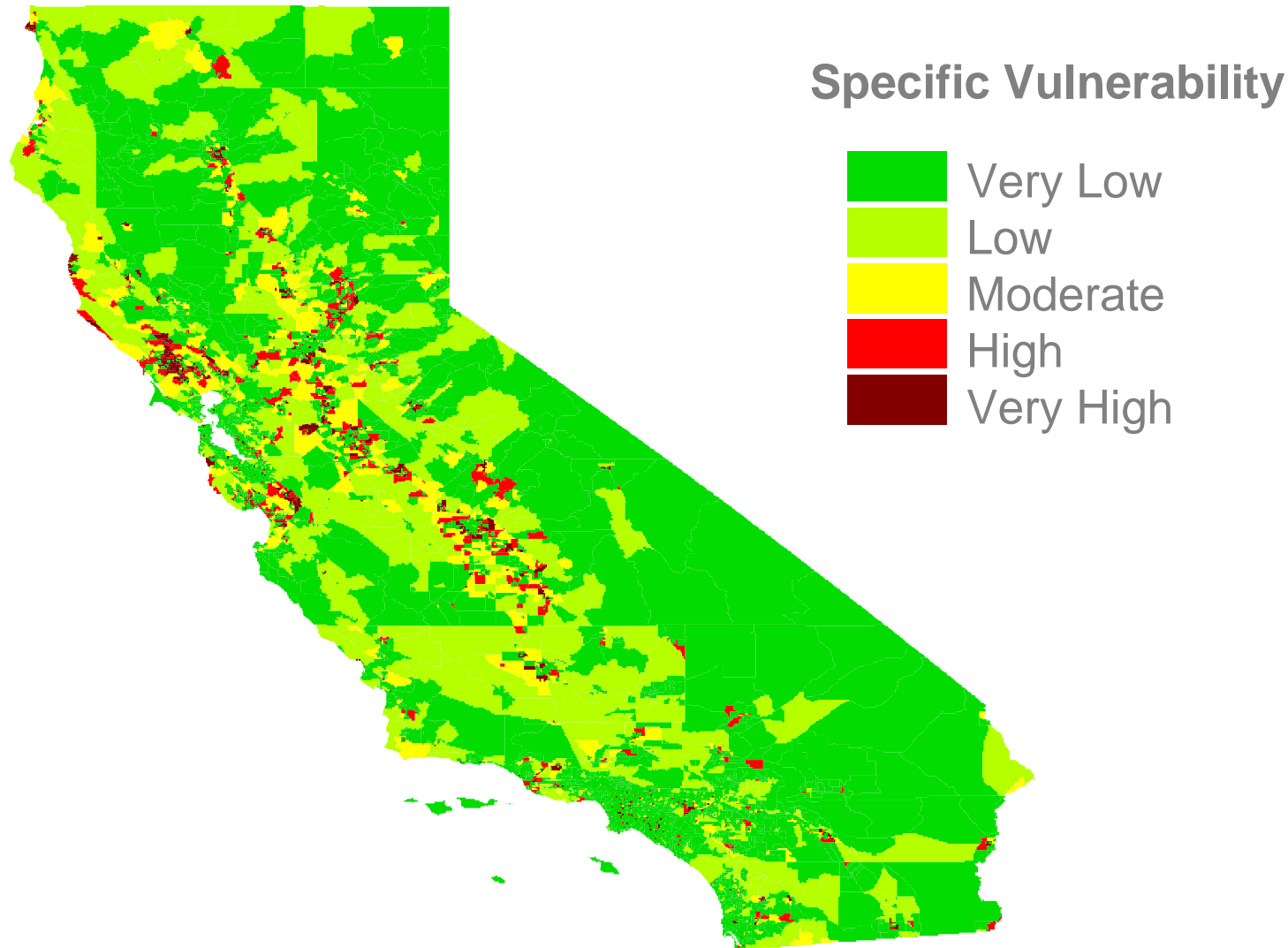
Estimated error in reported location of California drinking water wells in the DHS PICME Database[†].

- **Less than 330 feet** (green)
- **330 feet to 1,000 feet** (yellow)
- **1,000 feet to 3,300 feet** (red)
- **3,300 feet to 1.25 miles** (brown)
- **1.25 miles to 6.8 miles** (dark red)
- **6.8 miles to 27.3 miles** (gray)
- **Greater than 27.3 miles** (black)
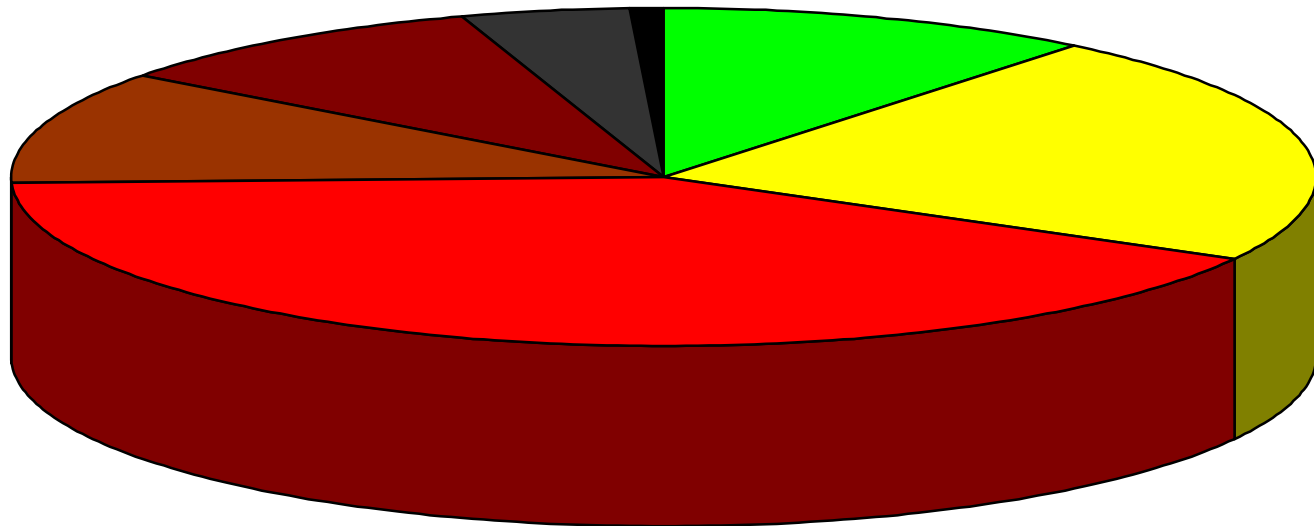
† Based on statistical samples from Orange and Santa Clara Counties

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Comparison of Errors in Positioning of California Public Drinking Water Wells

Legend:
- LLNL, Error in Repositioned Wells
- DHS, Error in Well Positions

Y-axis: 0%, 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%

X-axis categories:
- Less than 500 feet
- 500 feet to 1000 feet
- 1000 feet to 1/2 mile
- 1/2 mile to 1 mile
- Greater than 1 mile

Happel, Dooher & Beckenbach, 1999

Public Drinking Water Wells in California: Results of MTBE Analysis (January 1999)

Public Drinking Water Wells
(Community and Non-Transient Non-Community)

▲   38 Impacted Wells
🟡 7,436 Untested Wells
🟢 4,291 Tested Wells

Happel, Dooher & Beckenbach, 1999

Leaking Underground Fuel Tank Sites in California: Results of MTBE Analysis (January 1999)

Presence of MTBE at Open-Case LUFT Sites:

🔴 4,261 Sites with MTBE Detected

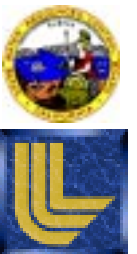🟠 9,960 Sites Unknown (or Not Reported)

🟢 1,514 Sites with No MTBE Detected

Happel, Dooher & Beckenbach, 1999

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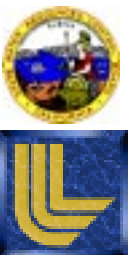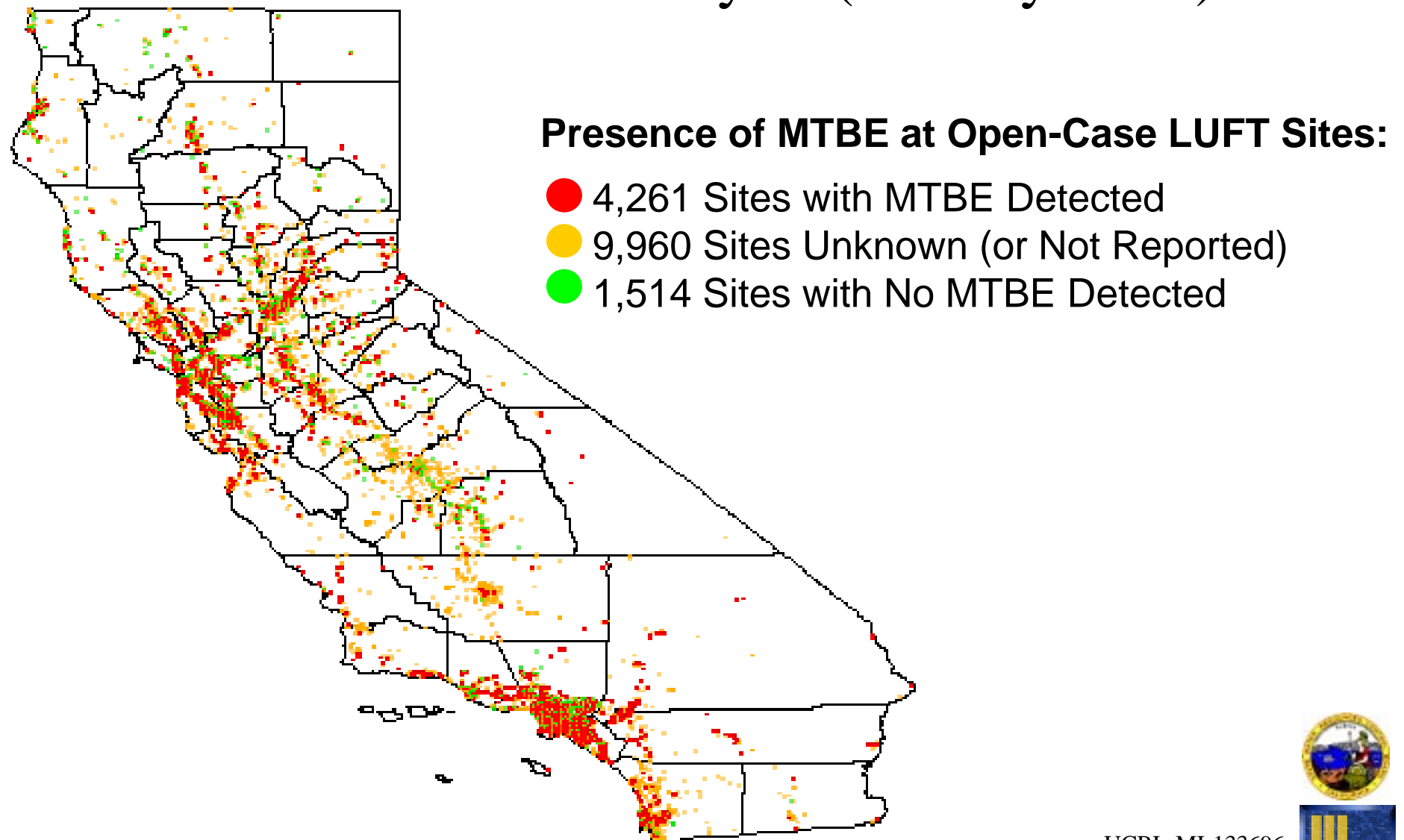
Public Drinking Water Wells in California: Estimated Number of Leaking Underground Fuel Tank (LUFT) Sites Within 1/2 Mile
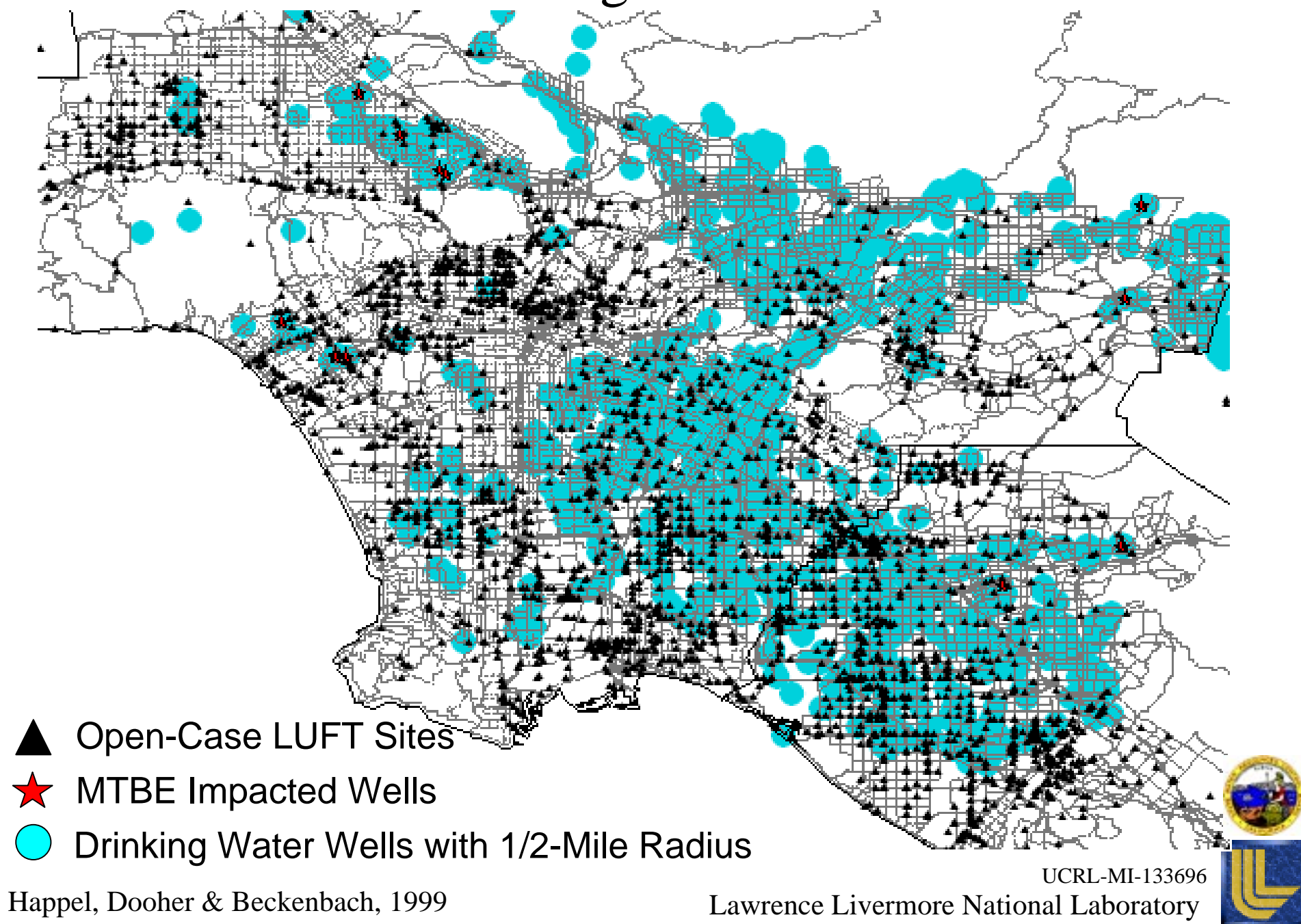
Public Drinking Water Wells
(Community and Non-Transient Non-Community)

- ● More than 10 LUFT sites within 1/2 mile
- ● 4-9 LUFT sites within 1/2 mile
- ● 1-3 LUFT sites within 1/2 mile
- ● No LUFT sites within 1/2 mile

Happel, Dooher & Beckenbach, 1999

Los Angeles Basin

Legend:

▲ Open-Case LUFT Sites

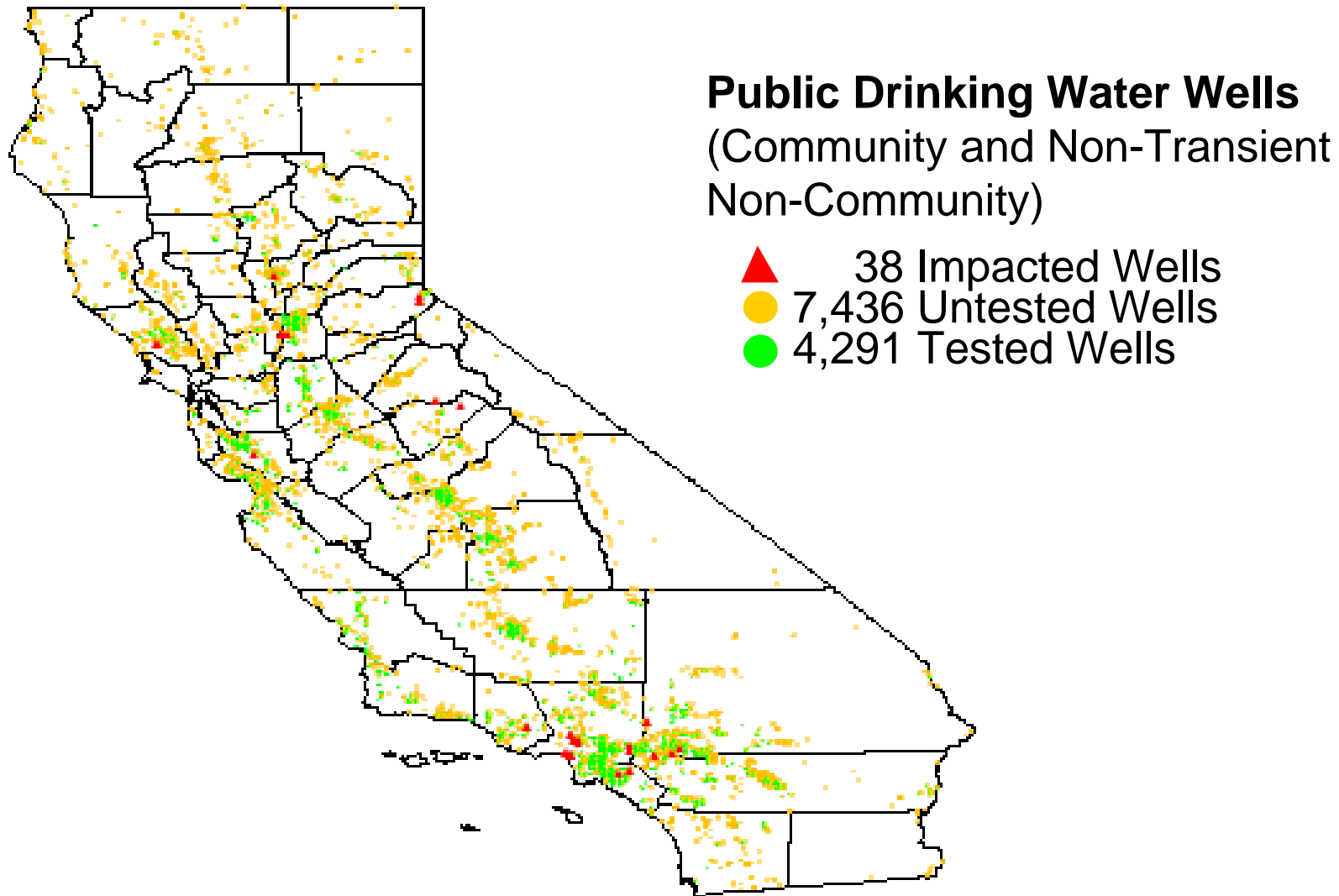★ MTBE Impacted Wells

● Drinking Water Wells with 1/2-Mile Radius

Happel, Dooher & Beckenbach, 1999
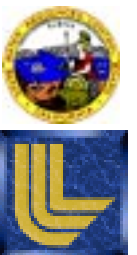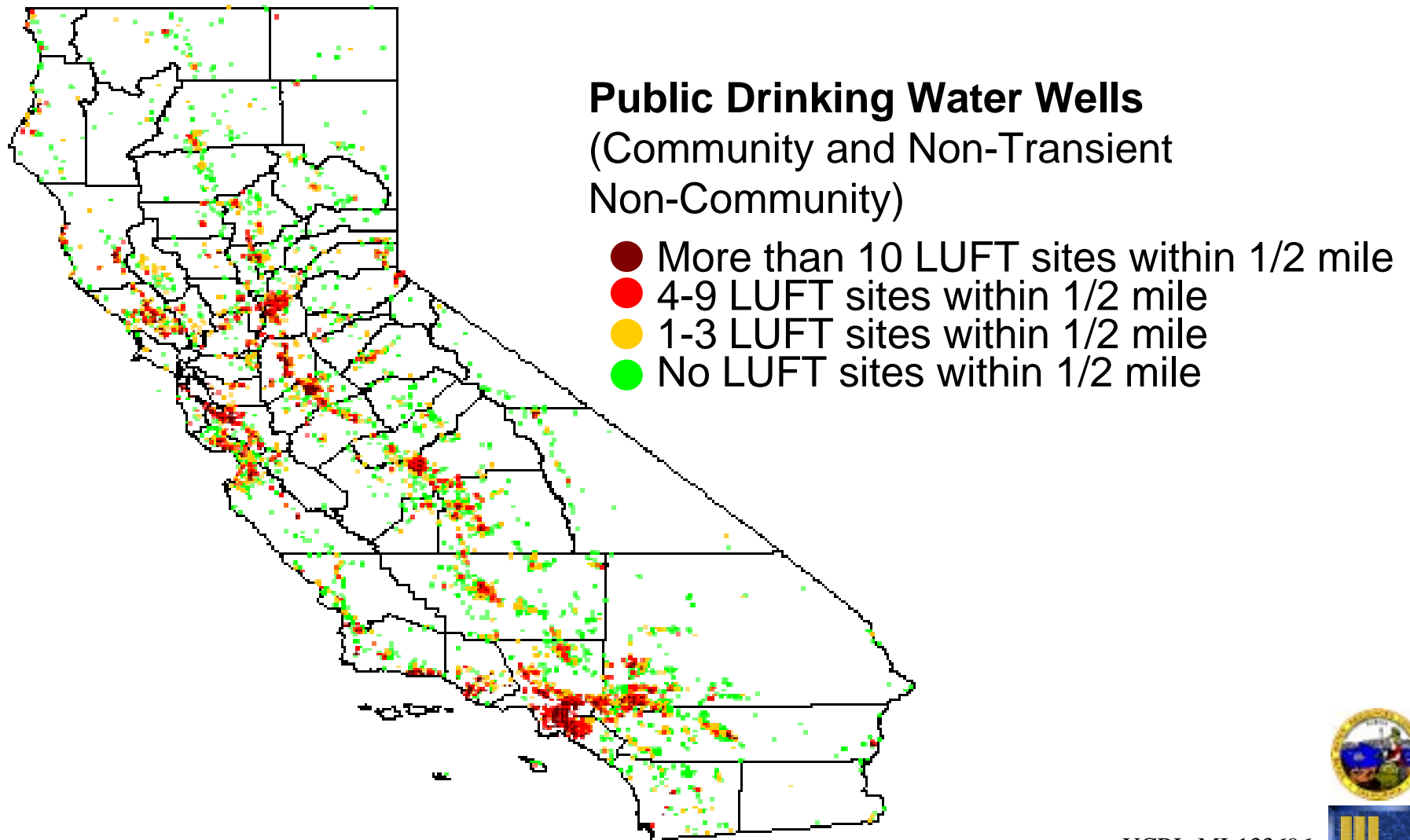
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Leaking Underground Fuel Tank Sites in California: Results of MTBE Analysis (January 1999)

Presence of MTBE at Open-Case LUFT Sites:

	Sites Within 1/2 Mile	Total Sites	Percent of Total
MTBE Detects	2,562	4,613	55.5%
MTBE Non Detects	831	1,514	54.9%
Unknown or Not Reported	5,511	9,960	55.3%

Percent of Open-Case Sites Impacted by MTBE: 75.3%

Estimated Number of MTBE Sites: Greater than 10,000

Estimated Number of MTBE Sites Within 1/2 Mile of a Drinking Water Well: 6,700

Happel, Dooher & Beckenbach, 1999

III. MTBE Plume Evolution:

Predictions of future MTBE plume growth (length and time)
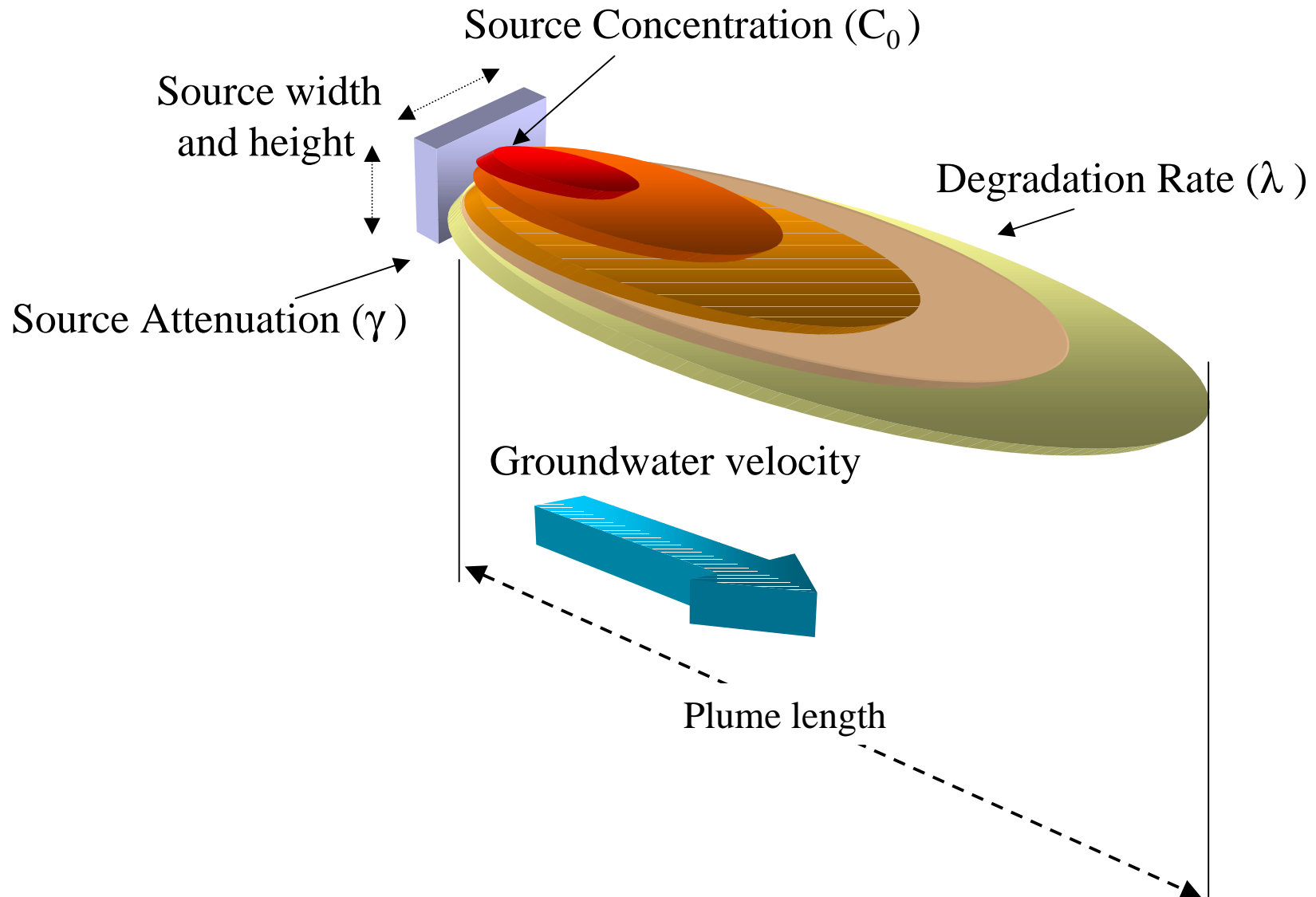
Monte Carlo analysis with *Cleary and Ungs* (1978) model

Source Concentration (C_0)

Source width and height

Degradation Rate (λ)

Source Attenuation (γ)

Groundwater velocity

Plume length

Monte Carlo analysis with *Cleary and Ungs* (1978) model
Model Inputs*:

- Source Concentration - 1999 Data from 4,300 LUFT sites
- Source Attenuation Half-life - Measured from 1,000 LUFT sites from 1988 to 1994
- Source Width - Based on tank dimensions
- Source Height - Based on variations in groundwater depth
- Hydraulic Conductivity - Measured from 100 LUFT sites
- Hydraulic Gradient - Measured from 1,000 LUFT sites
- Dispersivity (based on Gelhar et al., 1992)
- Plume length taken at 5 ppb contour
- No degradation rate

Data used in this model is derived from approximately 1,000 LUFT sites from throughout California

*Based on results measured at California LUFT sites, Dooher, March 1998

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Monte Carlo analysis of 2000 simulated plumes: Plume length at 10 years duration

Legend:
- Constant Source
- Decreasing Source

Categories (x-axis):
- Less than 100 feet
- 100 feet to 1000 feet
- 1000 feet to 1/2 mile
- 1/2 mile to 1 mile
- Greater than 1 mile

Happel, Dooher & Beckenbach, 1999

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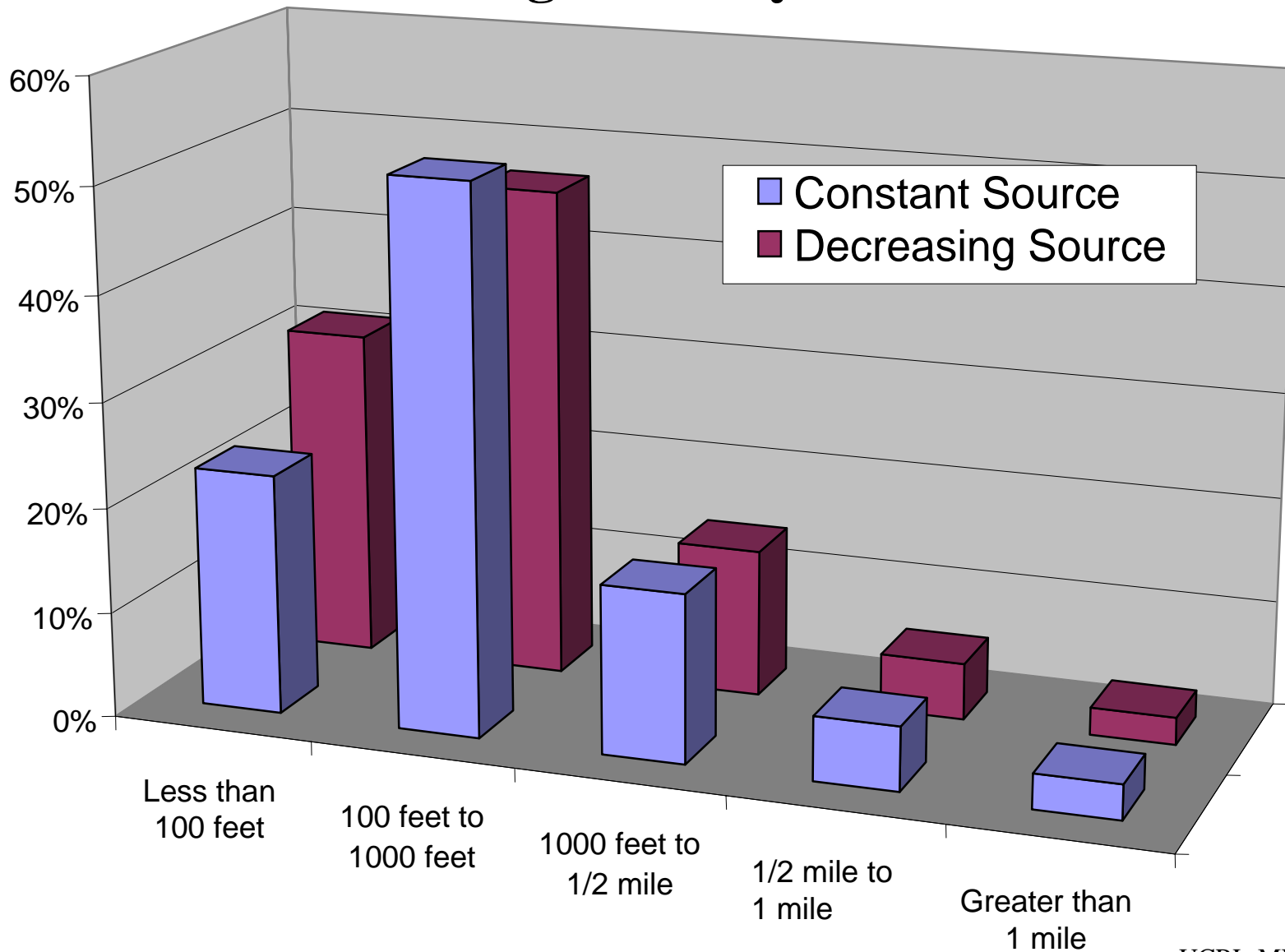
Monte Carlo analysis of 2000 simulated plumes: Plume length at 20 years duration
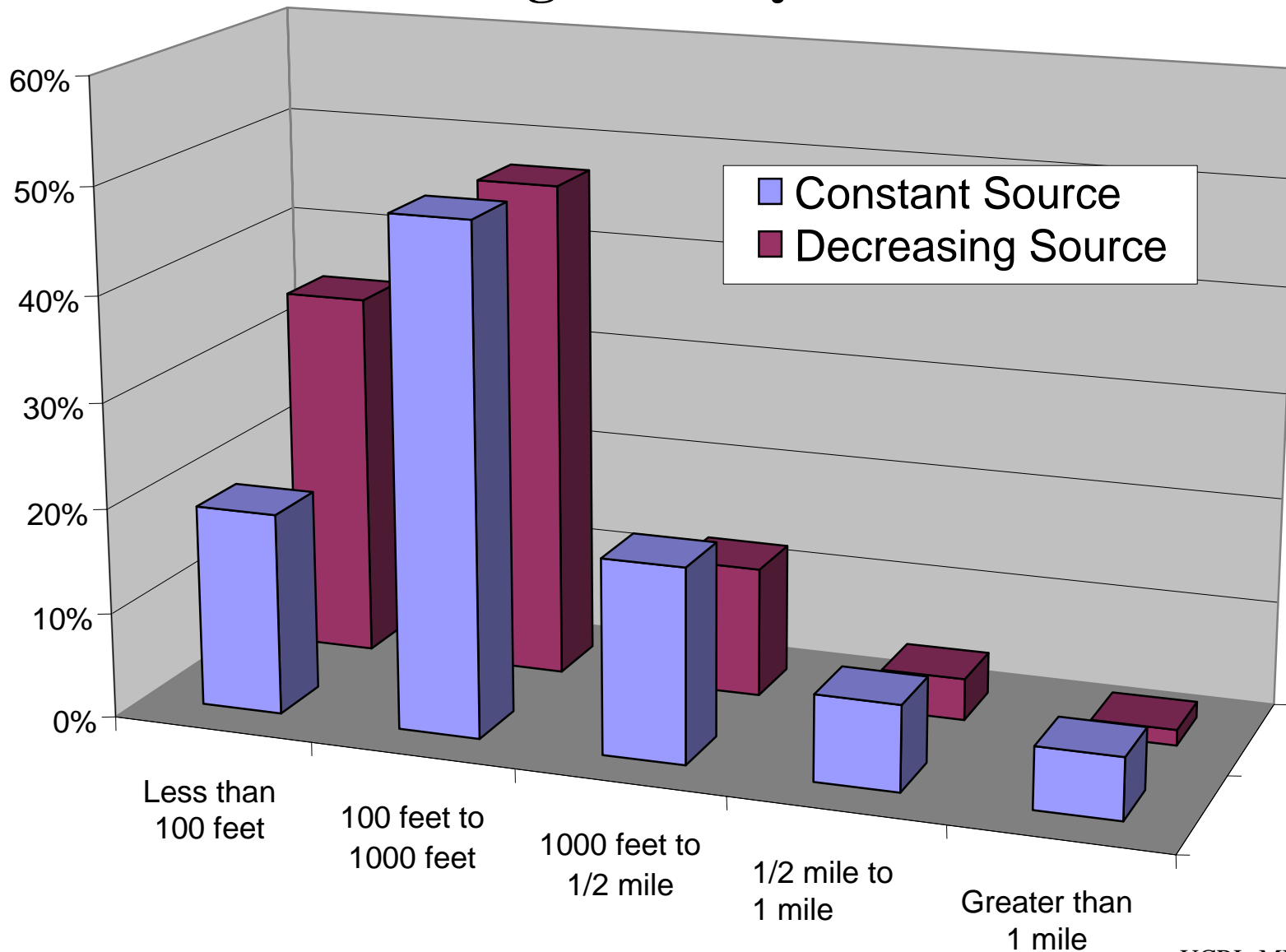
Happel, Dooher & Beckenbach, 1999

Monte Carlo analysis with *Cleary and Ungs* (1978) model:
Comparison of Plume Lengths Generated from Differing Source Concentrations

Assuming removal of tank and any continuing source (decreasing source):

ppb (parts per billion)	Plume Length Percentile (feet) 10 years		20 years		Percent of CA sites
	50th	95th	50th	95th	
<5-200	19	465	0	424	46%
200-5000	381	2,651	372	2,794	31%
5000-20000	913	5,772	1,079	6,581	13%
>20000	1,267	7,667	1,941	10,633	10%

Happel, Dooher & Beckenbach, 1999

Monte Carlo analysis with *Cleary and Ungs* (1978) model:
Comparison of Plume Lengths Generated from Differing Source Concentrations

Assuming continuing (constant) source :

ppb (parts per billion)	Plume Length Percentile (feet)				Percent of CA sites
	10 years		20 years		
	50th	95th	50th	95th	
<5-200	83	661	100	765	46%
200-5000	503	3,161	665	3,850	31%
5000-20000	972	6,031	1,412	8,013	13%
>20000	1,296	7,973	2,033	12,555	10%

Geographical Environmental Information Management System (GEIMS)
Data Transfer

RP CONSULTANT

LABORATORY

HARD COPY REPORT FROM EDF

EDF

FIELD SAMPLES TO LAB

GROUNDWATER BORE LOGS LITHOLOGY

SITE REGULATORY REPORT

AFTER VERIFICATION, DATA IS SUBMITTED OVER THE INTERNET TO THE STATE LUFT DATBASE (TEMPORARY FILE?)

SITE DATA IS ACCESSED AND ANALYZED USING WEB TOOLS

RWQCB

LEAD AGENCY CASE WORKER

REVIEWS RP REPORT AND ELECTRONIC DATA. APPROVES RP DATA.

ENTERS/UPDATES REGULATORY FIELDS VIA INTERNET

STATE SERVER ACTS AS FINAL REPOSITORY FOR CENTRALIZED DATABASE AND WEB ACCESS TOOLS

REGIONAL SERVER ACTS AS DATABASE REPOSITORY AND WEB TOOL SERVER

SITE DATA IS ACCESSED AND ANALYZED BY REGULATOR USING WEB TOOLS

STATE UPDATES THE SWRCB SERVER

Happel, Dooher & Beckenbach, 1999

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Benefits of GEIMS Design

This system has the potential to dramatically <u>transform</u> the way clean-up decisions are made by regulators and industry nation-wide.

- **Designed to be <u>inclusive of any contaminant</u> (NOT limited to MTBE and fuel compounds)**
- Uses electronic data transfer & automated importing of data
- High degree of data quality control
- Use of internet for regulatory, industry, and public access
- On-line tools for analysis of data
- Public domain software

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